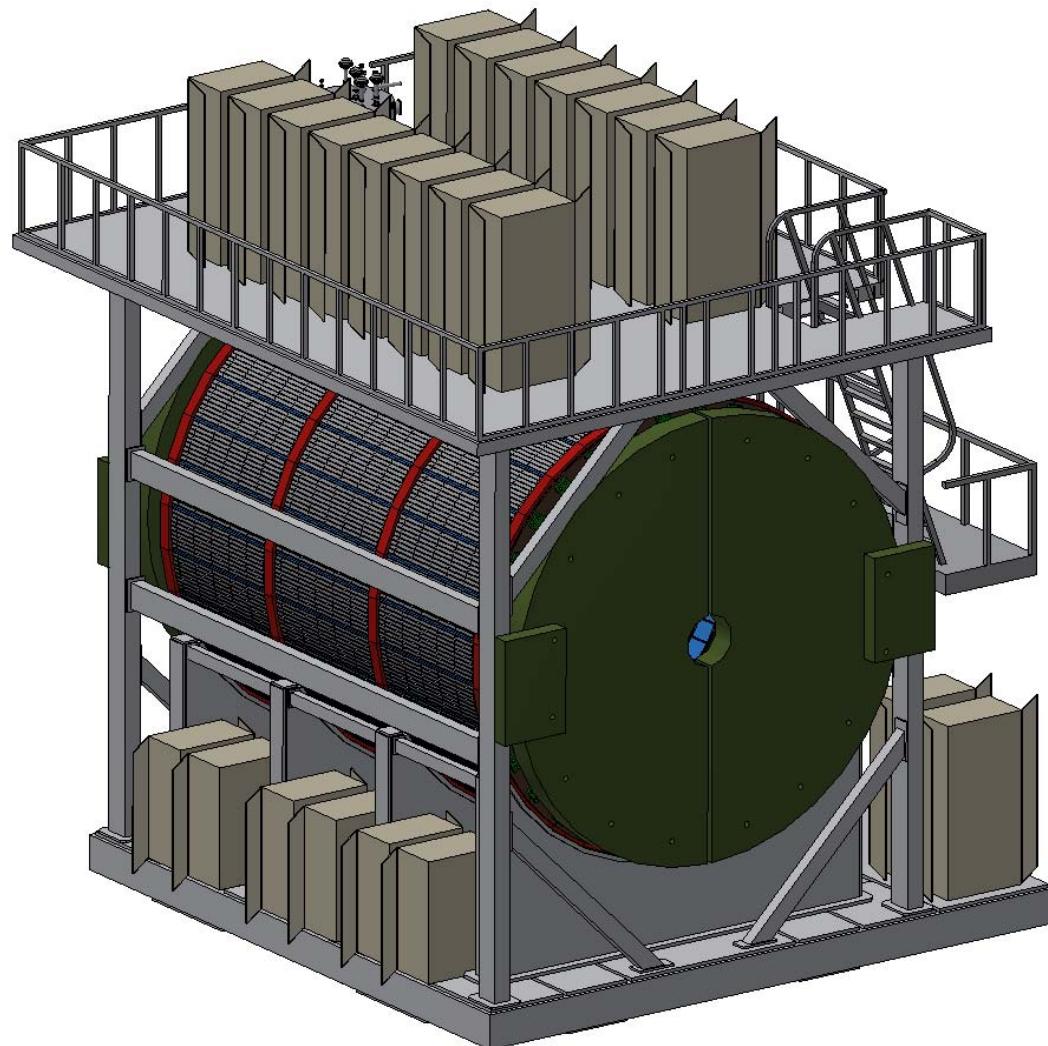


Overview of the PHENIX HCal

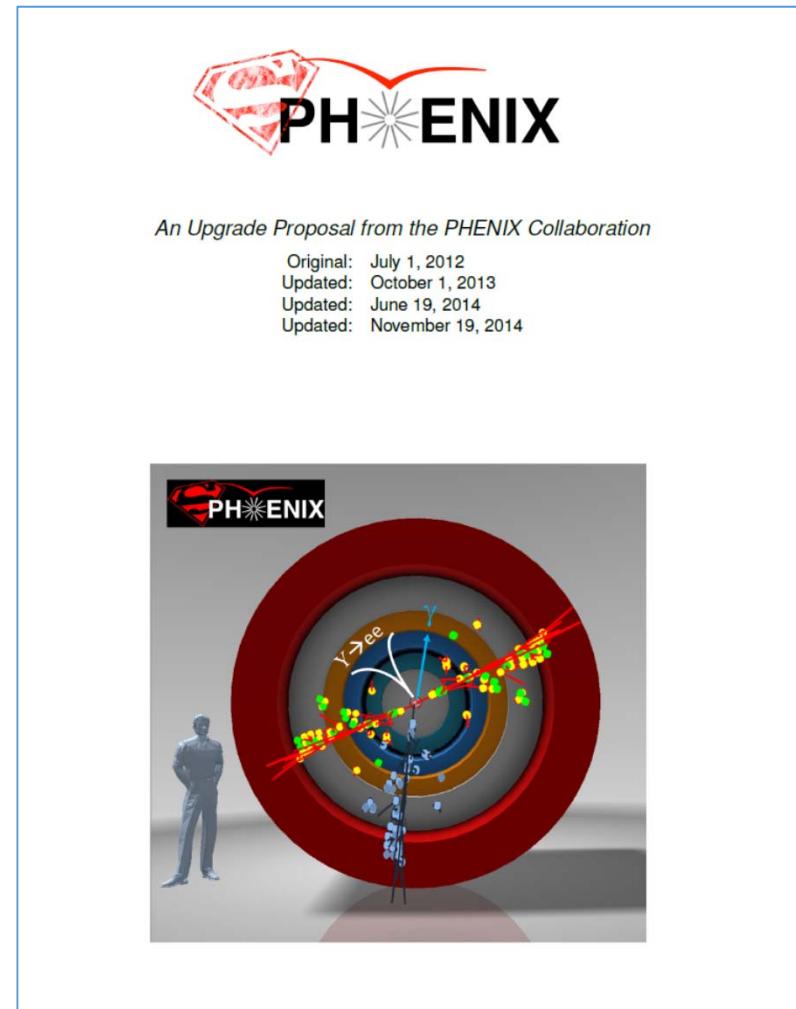


J. Lajoie
Iowa State
University

Introduction, Physics and Concept

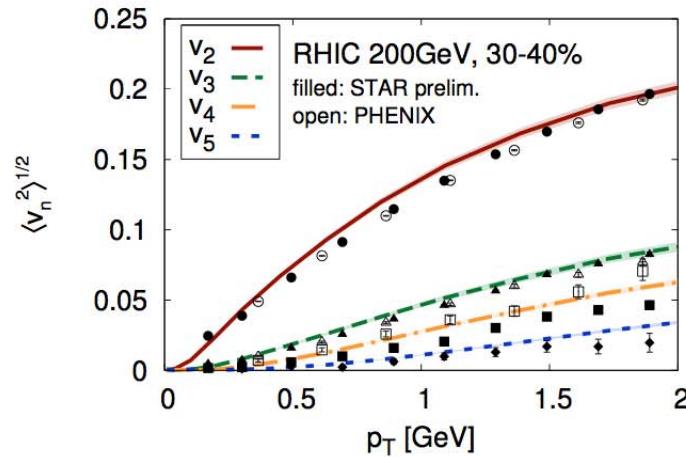
- Physics Goals
- sPHENIX in a Nutshell
- Overview of HCal design and requirements

Extensive additional information available in PHENIX proposal.

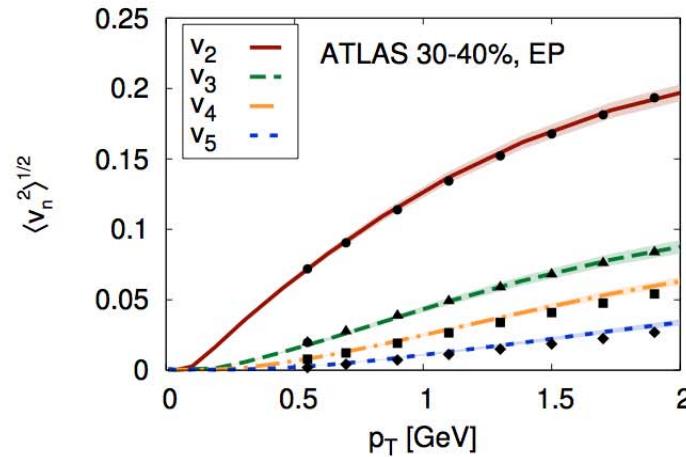


arXiv:1501.06197

The Strongly Coupled QGP



$$\eta/s \approx 0.12 \text{ at } \sqrt{s} = 0.2 \text{ TeV}$$



$$\eta/s \approx 0.2 \text{ at } \sqrt{s} = 2.76 \text{ TeV}$$

suggestions of stronger coupling at RHIC from flow measurements in the region near the transition temperature

how do jet related properties (\hat{q} , etc...) differ from RHIC to LHC?

change the initial temperature and the distance scale on which the medium is probed

Probes of the Underlying Physics

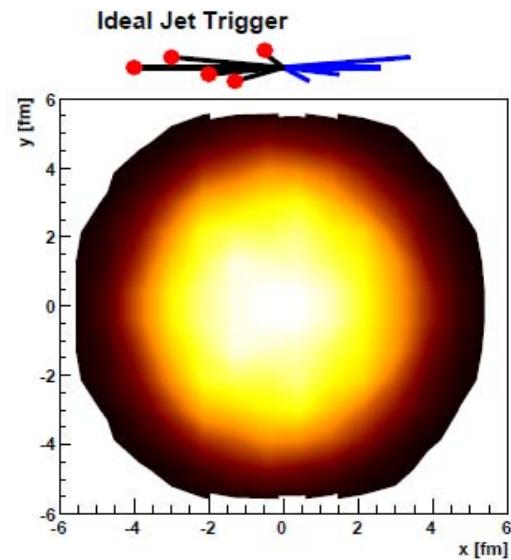
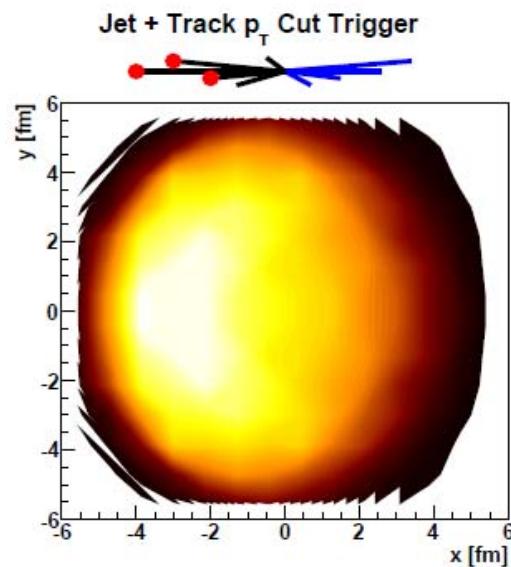
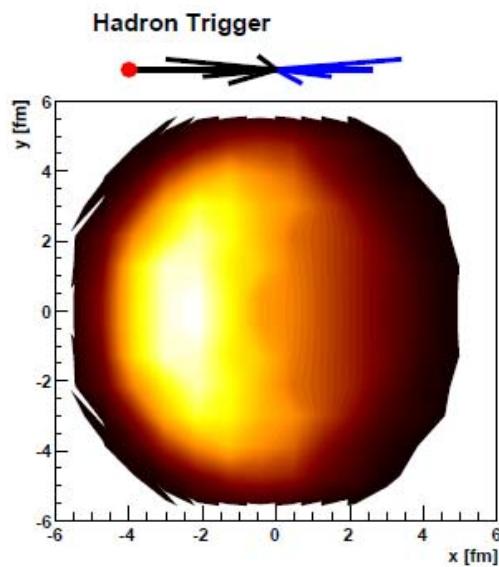
- Jets and jet correlations for different size (R) jets
- Correlations of jets and photons with hadrons
- Photons and photon-jet correlations
- Fragmentation functions
- ...

The sPHENIX HCAL is a critical component
for all these measurements.

Biases in Jet Measurements

how do jet measurement correlate with where the jet originates?

calc: T. Renk

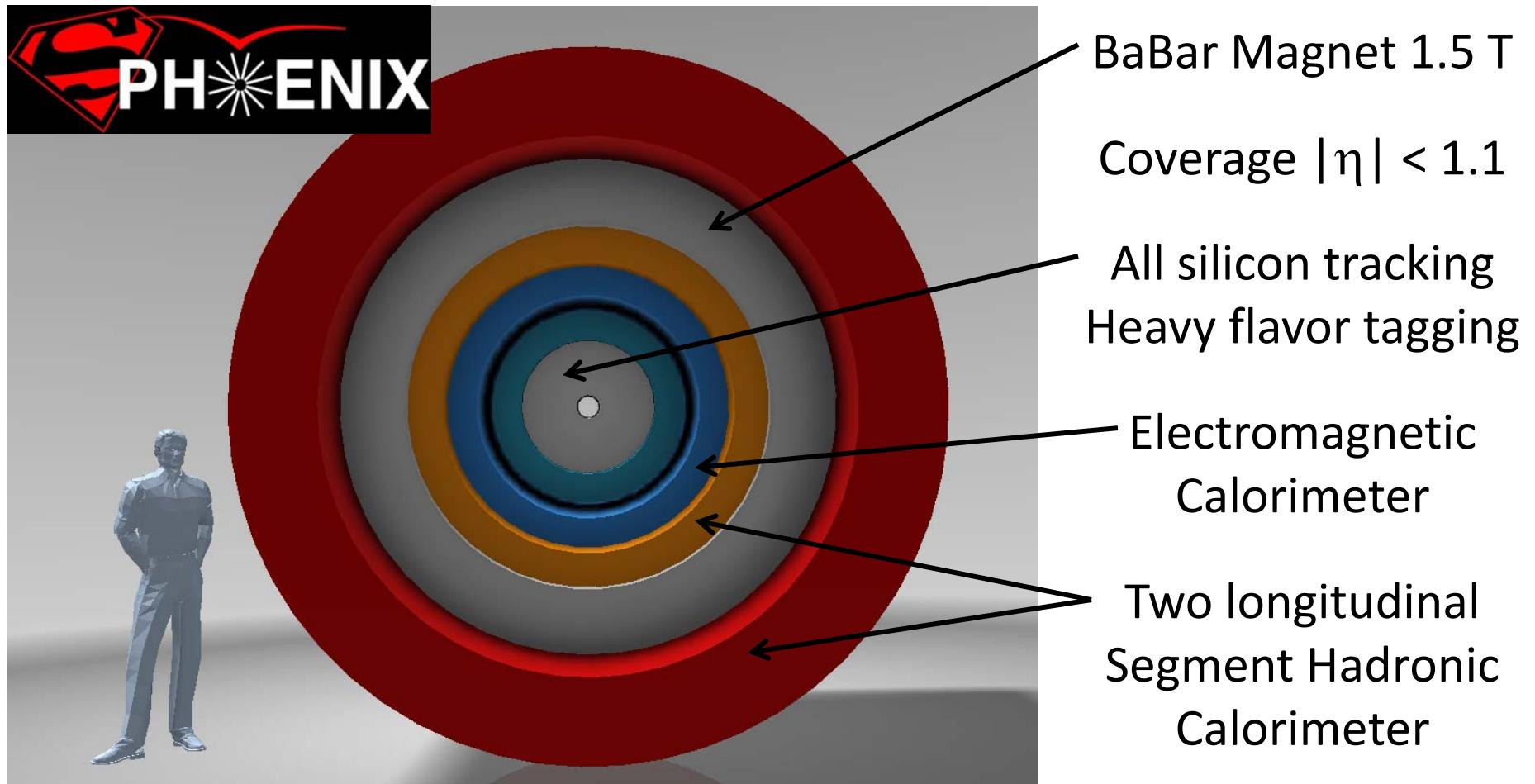


STAR



sPHENIX

sPHENIX in a Nutshell



Common Silicon Photomultiplier readout for Calorimeters
Full clock speed digitizers, digital information for triggering

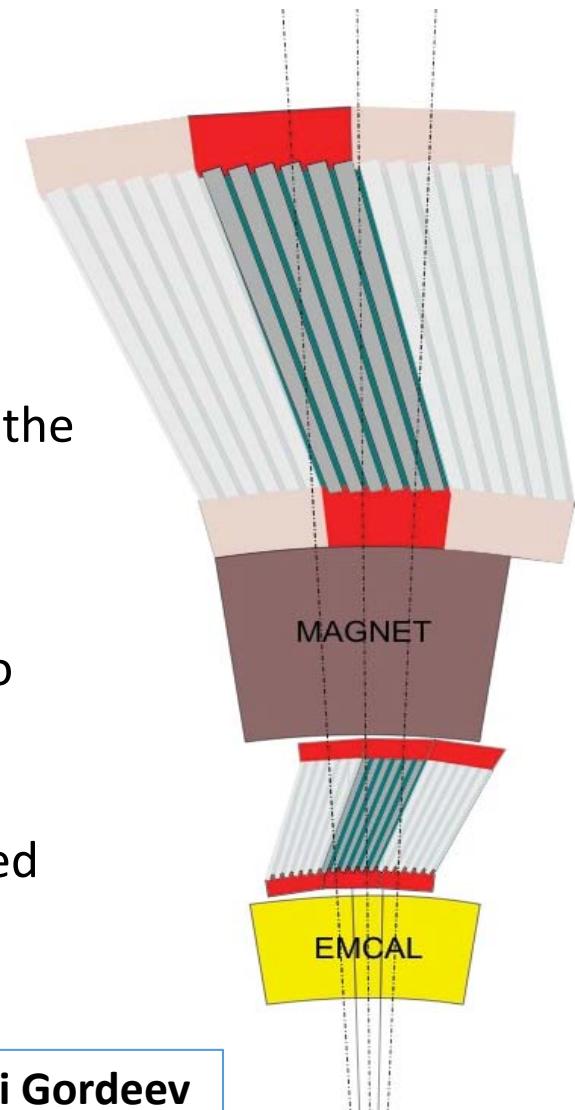
sPHENIX HCal Design

Hadronic calorimeter is comprised of tapered steel plates with interleaved scintillator tiles.

The outer steel plates run along the beam axis and act as the magnetic field flux return
(covered in magnet review of Jan. 2015)

Plates tilted at 32° (12°) angle for inner (outer) sections to avoid channeling.

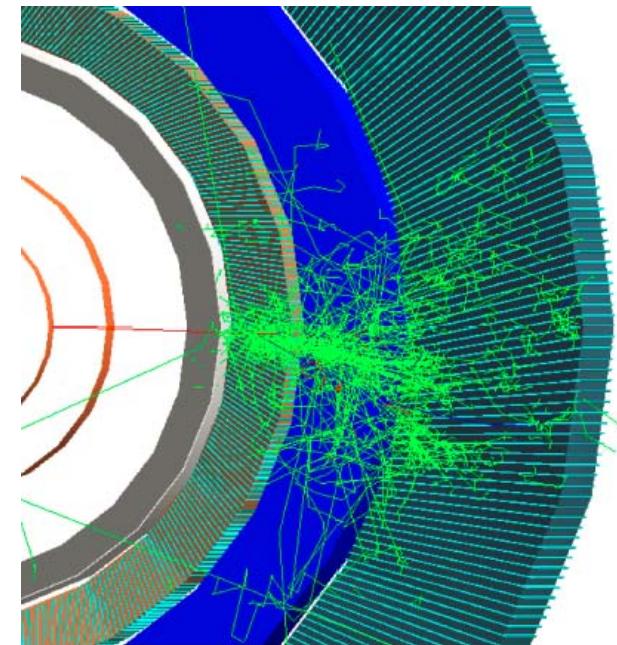
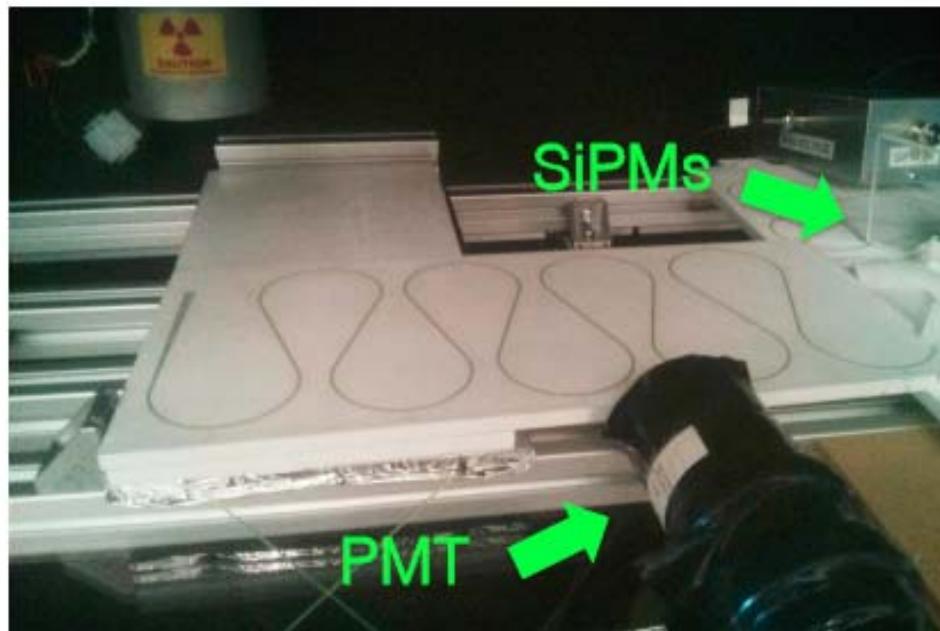
Embedded wavelength shifting fibers in scintillator coupled to SiPM for reading out light.



Much more detail in the talks from Rich Ruggiero and Anatoli Gordeev

Coming Attractions ...

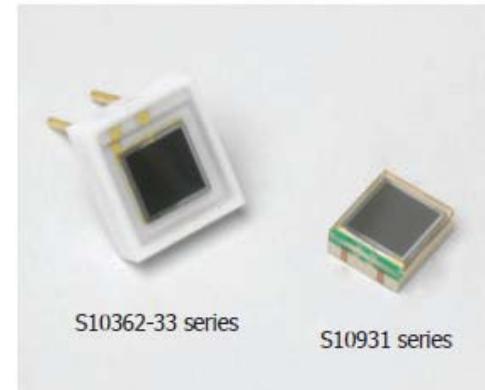
Details including prototype / test beam comparison in Liang's talk.



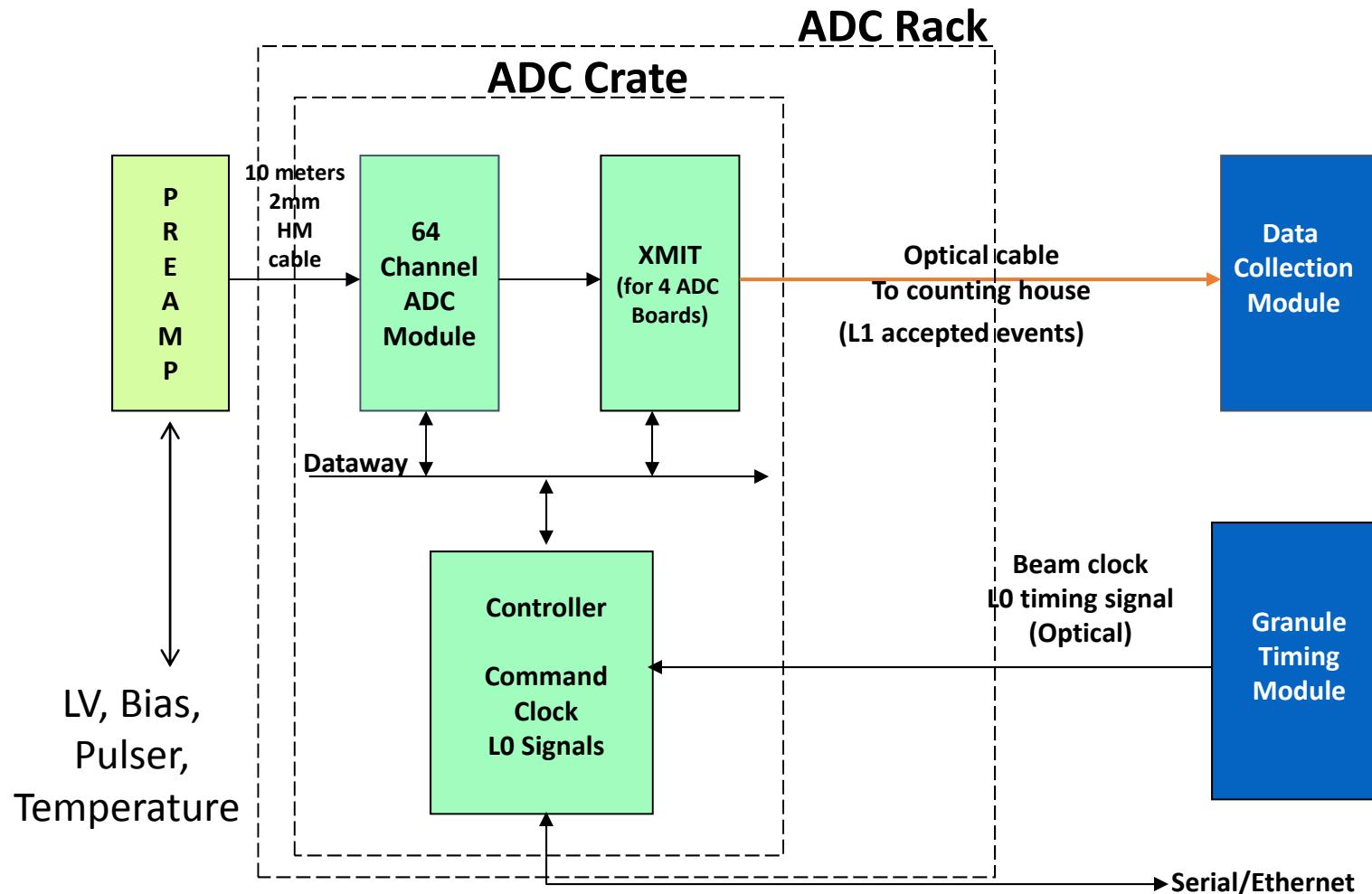
Test stand tile characterization shown in Jamie's talk.

HCal Electronics

- SiPM preferred optical sensor:
 - Large gain, $\sim 10^5$
 - Dynamic range: $\sim 10^4$
 - Immune to magnetic fields
- Local amplification and gain stabilization
- 2mm Hard Metric cable used to transmit analog signals to digitizers, cross talk measured to 10^{-3}
- Digitization nearby (off detector) using 14 bit ADCs at 60MHz
- Digitizer boards produce trigger primitives for trigger generation
- Potential concerns:
 - Temperature dependence
 - Neutron Damage

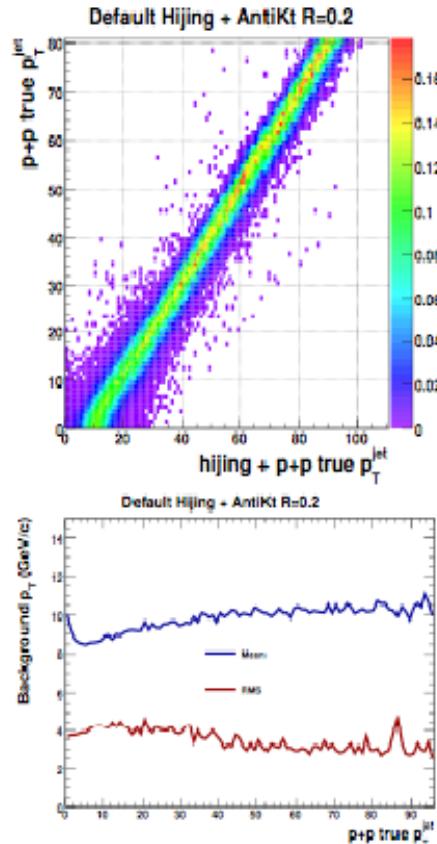


sPHENIX HCal Front End

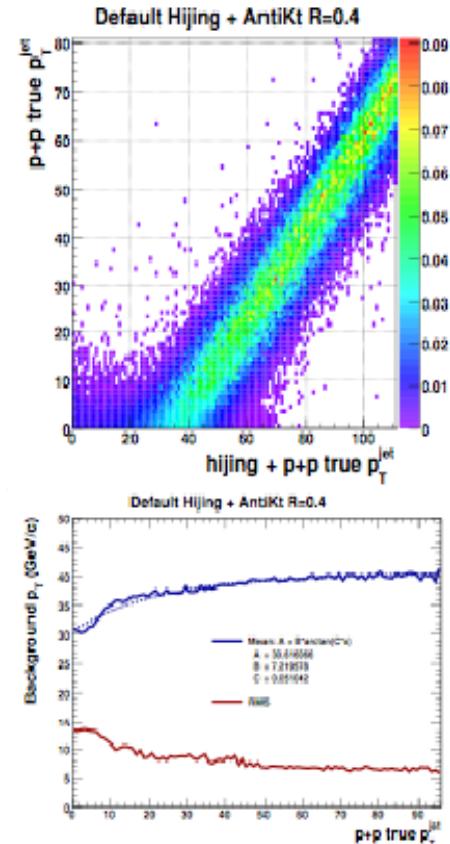


The Challenge of Heavy Ions

- Underlying event (UE) adds energy to measured jets in heavy ion collisions
- Fluctuations in UE degrade jet energy resolution
- At lower p_T fluctuations in UE can appear to be jets—“fake” jets

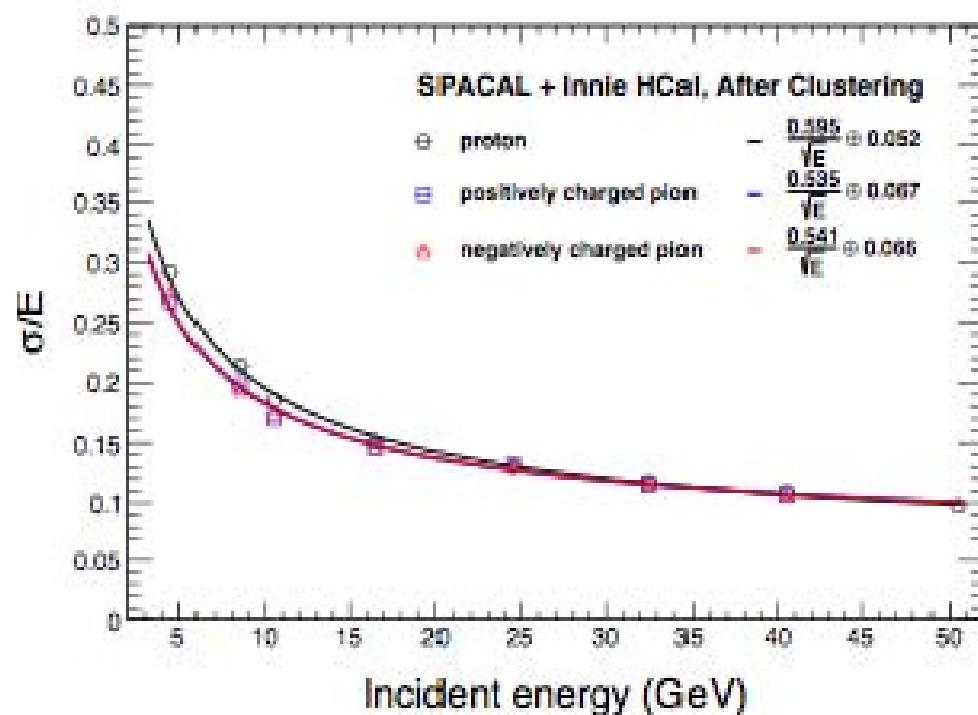
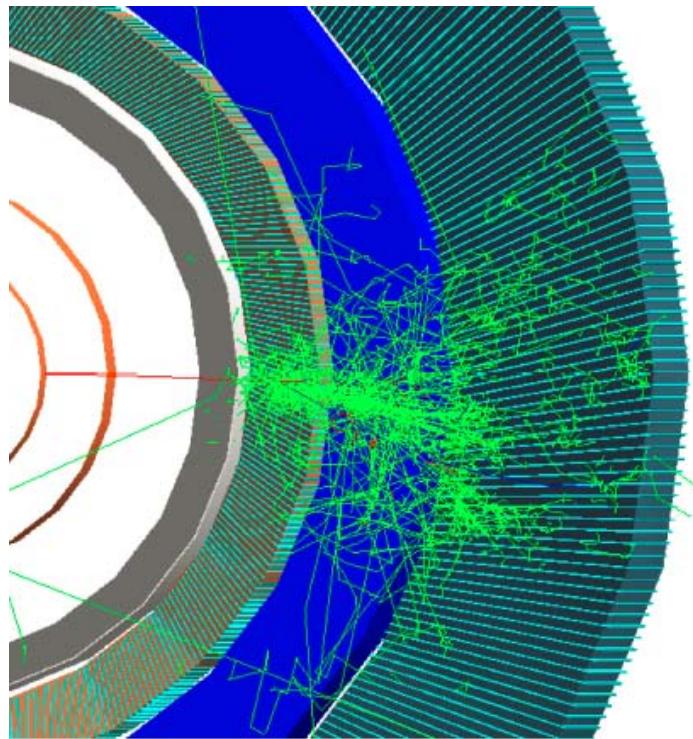


$R = 0.2, b = 4.4\text{fm}$
 $\Sigma \text{ background } \sim 10 \text{ GeV}$
background RMS $\sim 3.5\text{GeV}$



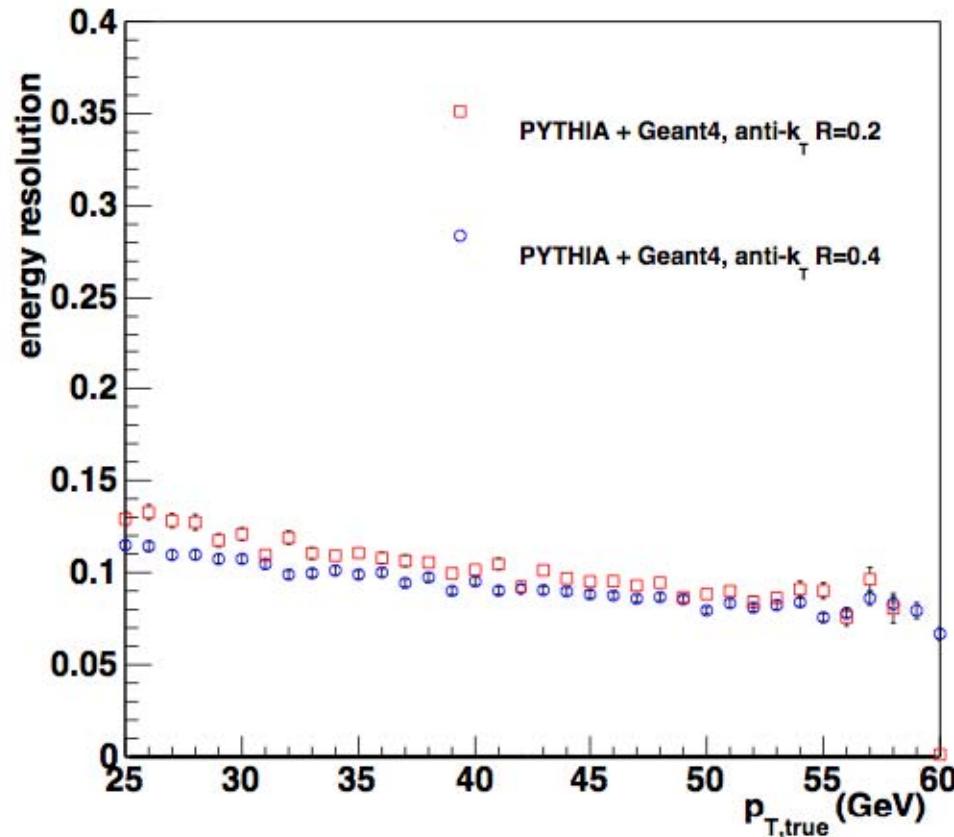
$R = 0.4, b = 4.4\text{fm}$
 $\Sigma \text{ background } \sim 40 \text{ GeV}$
background RMS $\sim 7\text{GeV}$

sPHENIX in GEANT4



Complete sPHENIX geometry implemented in GEANT4
Hadrons propagated through, EMCAL, Inner HCal & Outer HCal

Jet Energy Resolution – p+p



$$\sigma_E/E$$

R=0.2: 65%/ \sqrt{E}

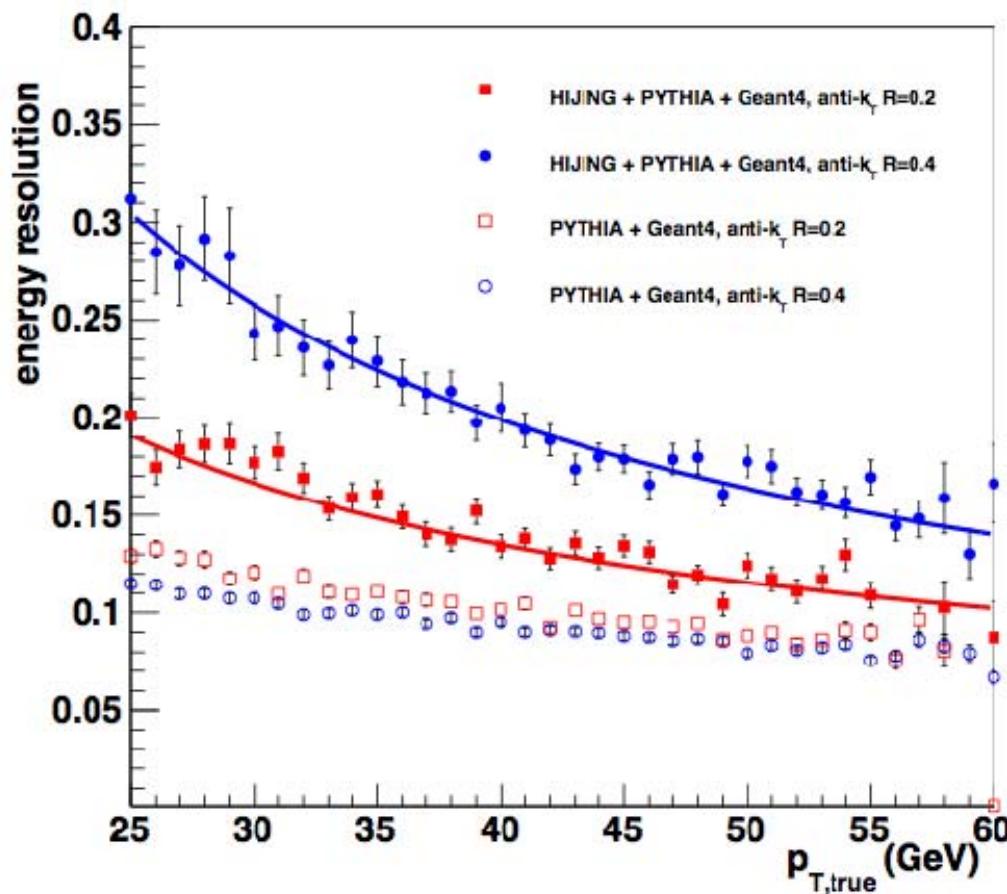
R=0.4: 60%/ \sqrt{E}

both: small constant term

these resolutions are substantially better than
the required resolution

Jet Energy Resolution – Au+Au

PYTHIA events embedded into central HIJING events



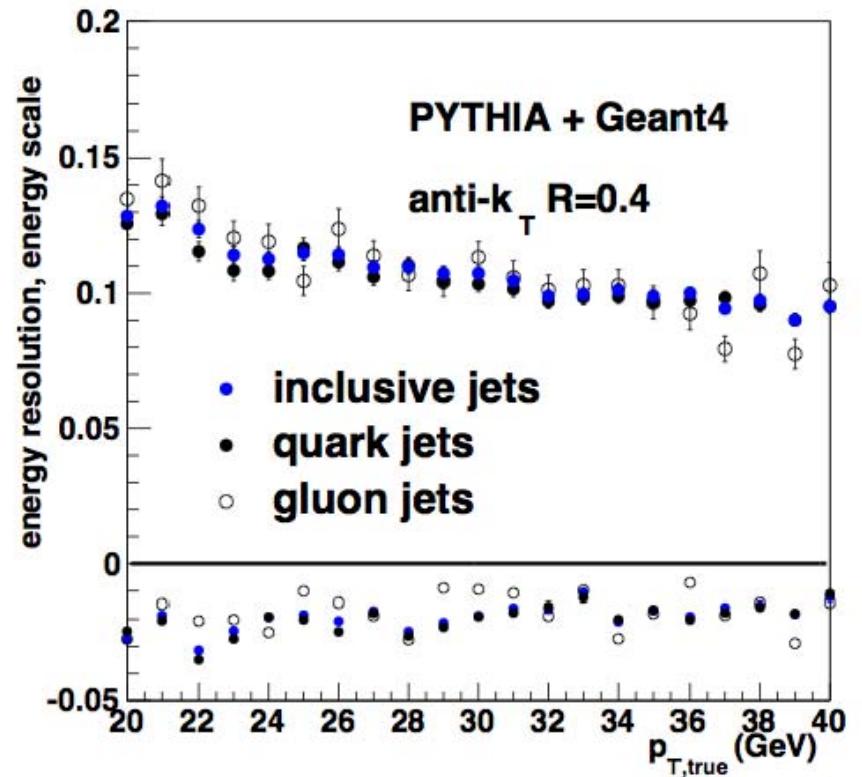
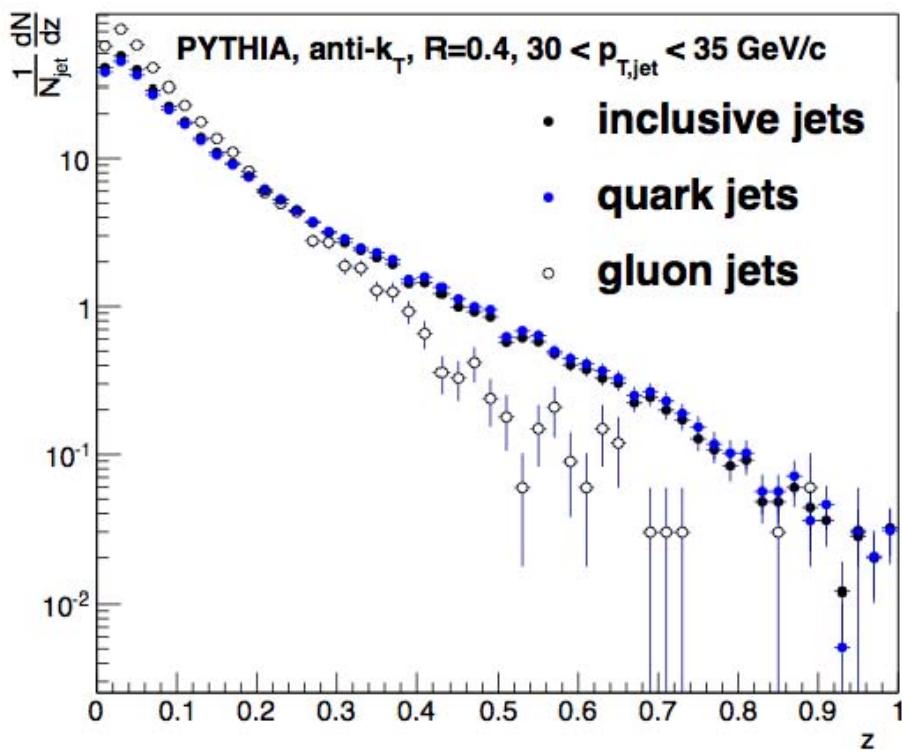
lines: p+p resolution \oplus
UE smearing

7 GeV for R = 0.4

3.5 GeV for R = 0.2

underlying event
determines jet
performance in AA

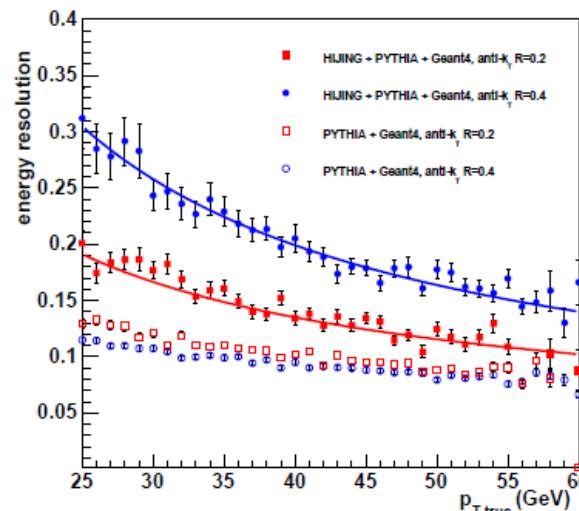
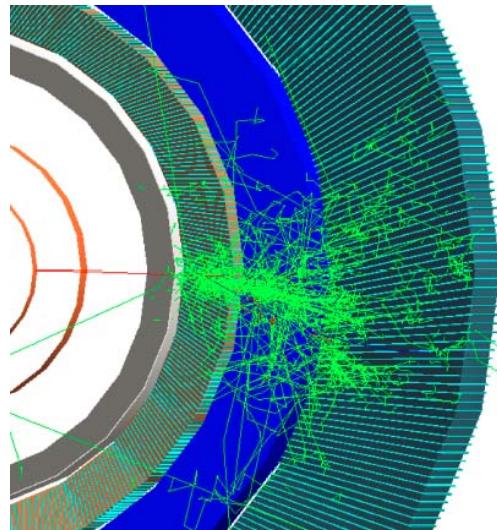
Fragmentation Bias



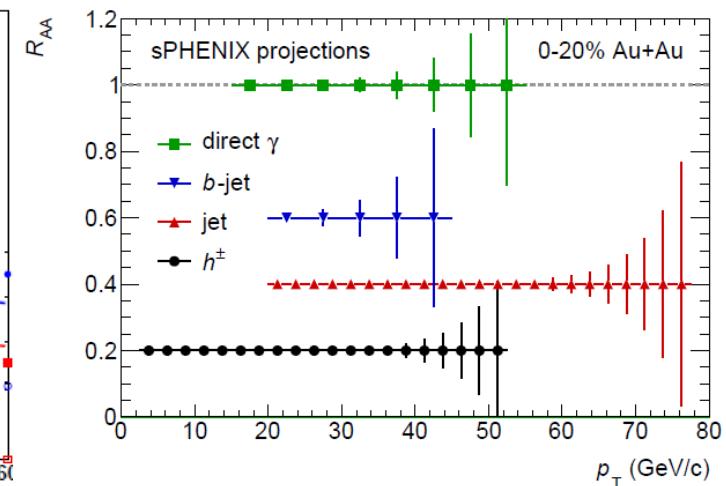
jet resolution similar for quark & gluon jets
gluon jets have softer FF (like a quenched jet)

Summary of HCal Requirements

- Jet energy resolution $< 120\%/\sqrt{E}$ delivers the key physics performance
 - Drives hadronic calorimeter resolution specification: $< 100\%/\sqrt{E}$
- Constant term in energy resolution not a driver since highest energy jets ~ 70 GeV
 - In Au+Au central, underlying event $R=0.2$ (0.4) is 10 (40) GeV
 - Drives light collection uniformity specification to better than 20%
- Jet size dependence – requires segmentation 0.1×0.1
- Large dijet acceptance – requires pseudorapidity coverage $-1.0 < \eta < +1.0$
- Input to Level-1 triggering – tile level is sufficient for p+p and p+A requirements



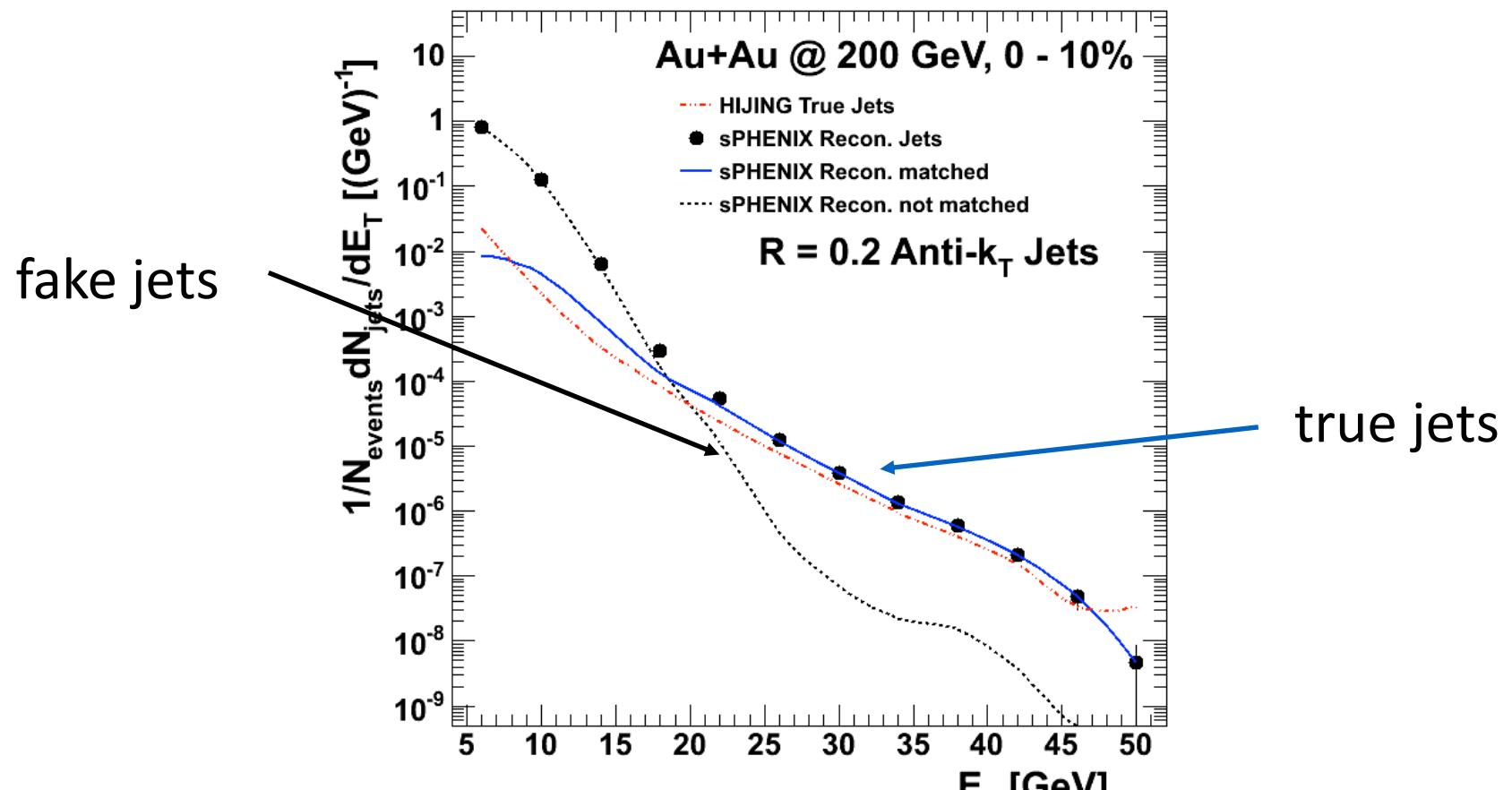
SPHENIX HCAL BNL Review



HCal Issues Addressed to Date

- Simulation studies show that the HCal as designed will meet physics performance needs
- A first version of a tilted-plate HCal prototype was built and tested at FNAL. R&D results look promising.
- Engineering design exists containing reasonable details showing how both the Inner and Outer HCal can be built and installed.
- There is a draft of a Project plan for the HCal that has a bottoms-up cost estimate, with a resources loaded schedule. It is being scrubbed and improved by subsystem experts.

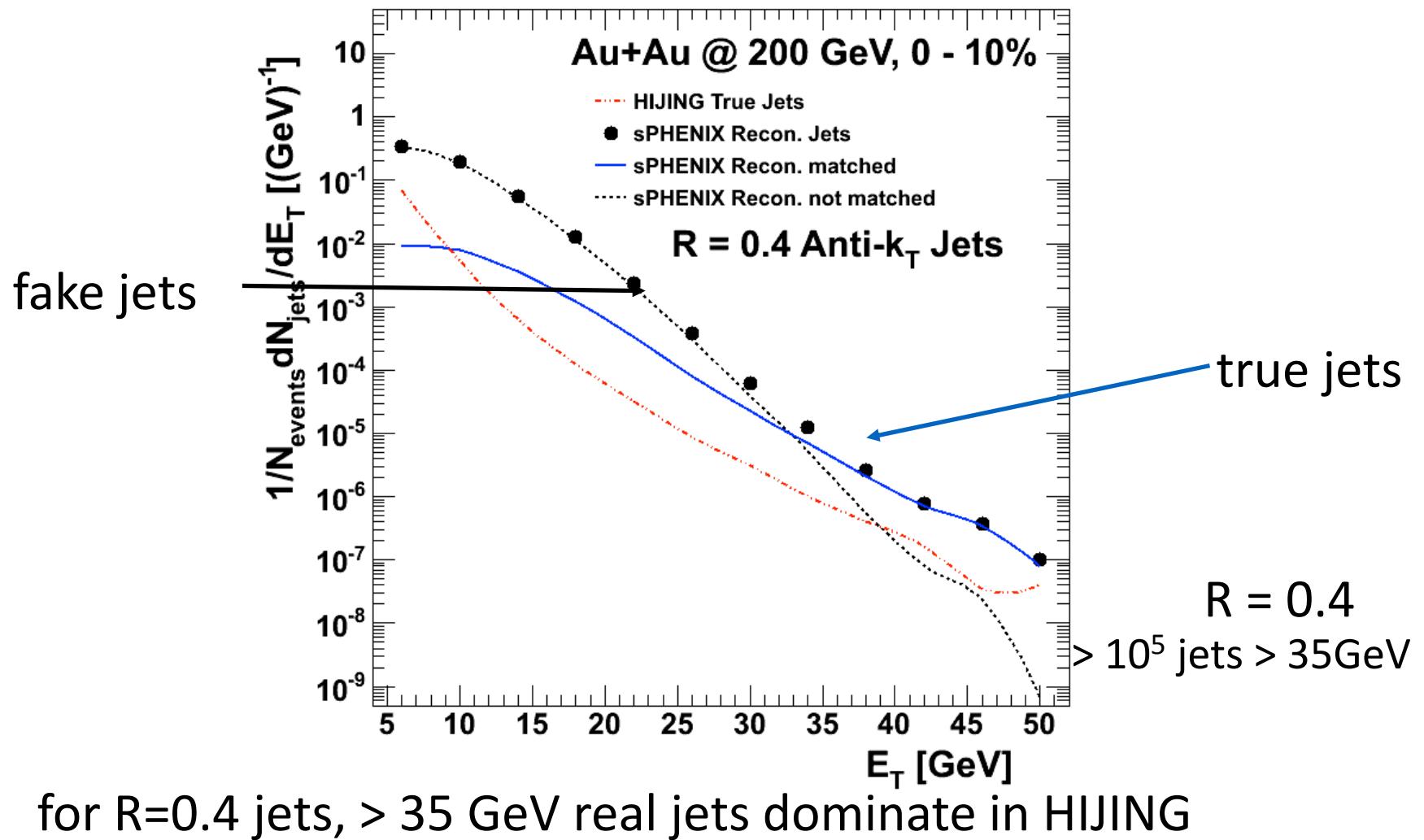
BACKUP



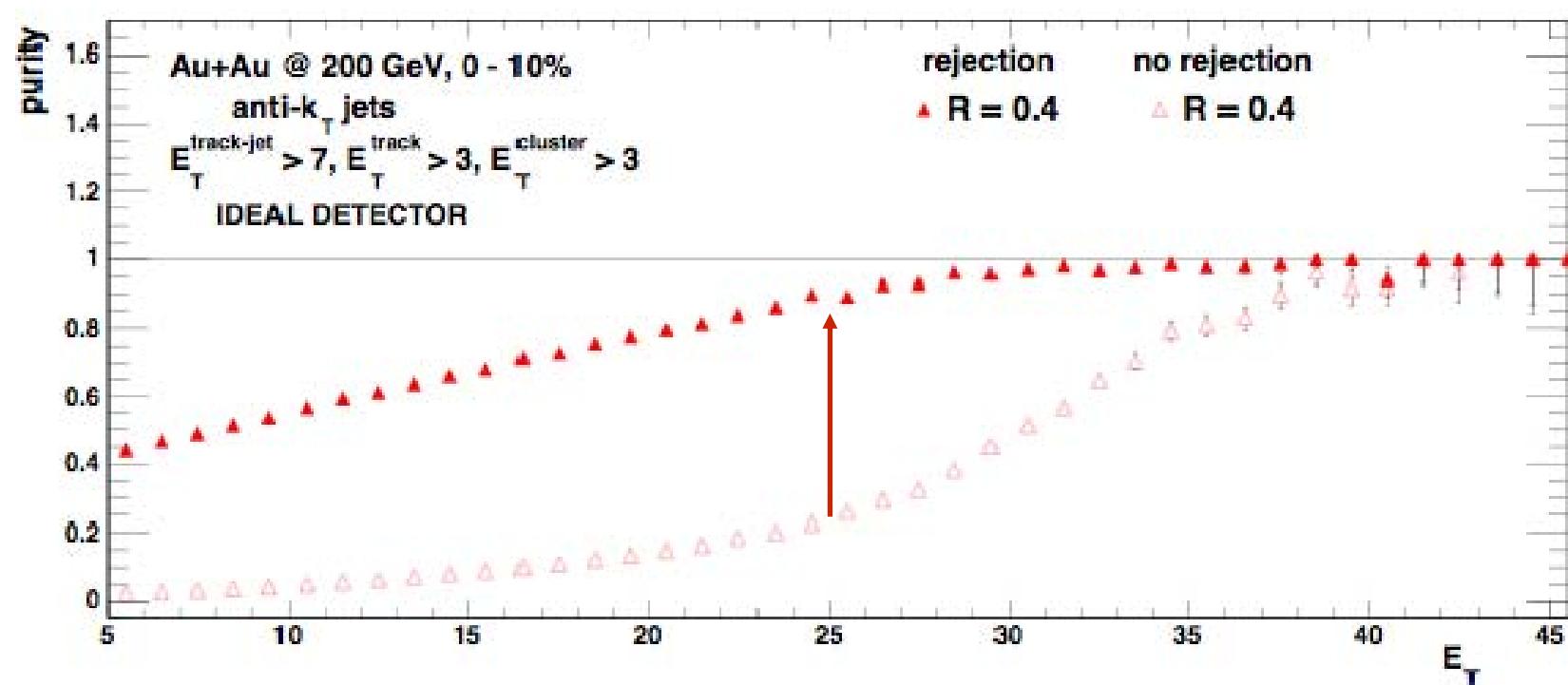
for R=0.2 jets, > 20 GeV real jets dominate in HIJING

Crate and Rack Requirements

- 48 Digitizer boards required for HCal
- 4 Digitizer boards per XMIT Group- 12 XMIT Boards
- 6U Crate
 - 1 Crate controller
 - 3 XMIT Groups
 - 1 XMIT Board
 - 4 Digitizer Boards
 - 16 Total modules per Crate (20 slots)
 - 4 slots reserved for trigger modules
- HCal requires 4 total crates (1 per quadrant) for digitizers
- Four additional crates required for voltage/bias distribution.
- 12 DCM-II Fibers
 - 8 DCM-II channels per module
 - 2 DCM-II modules for full HCal

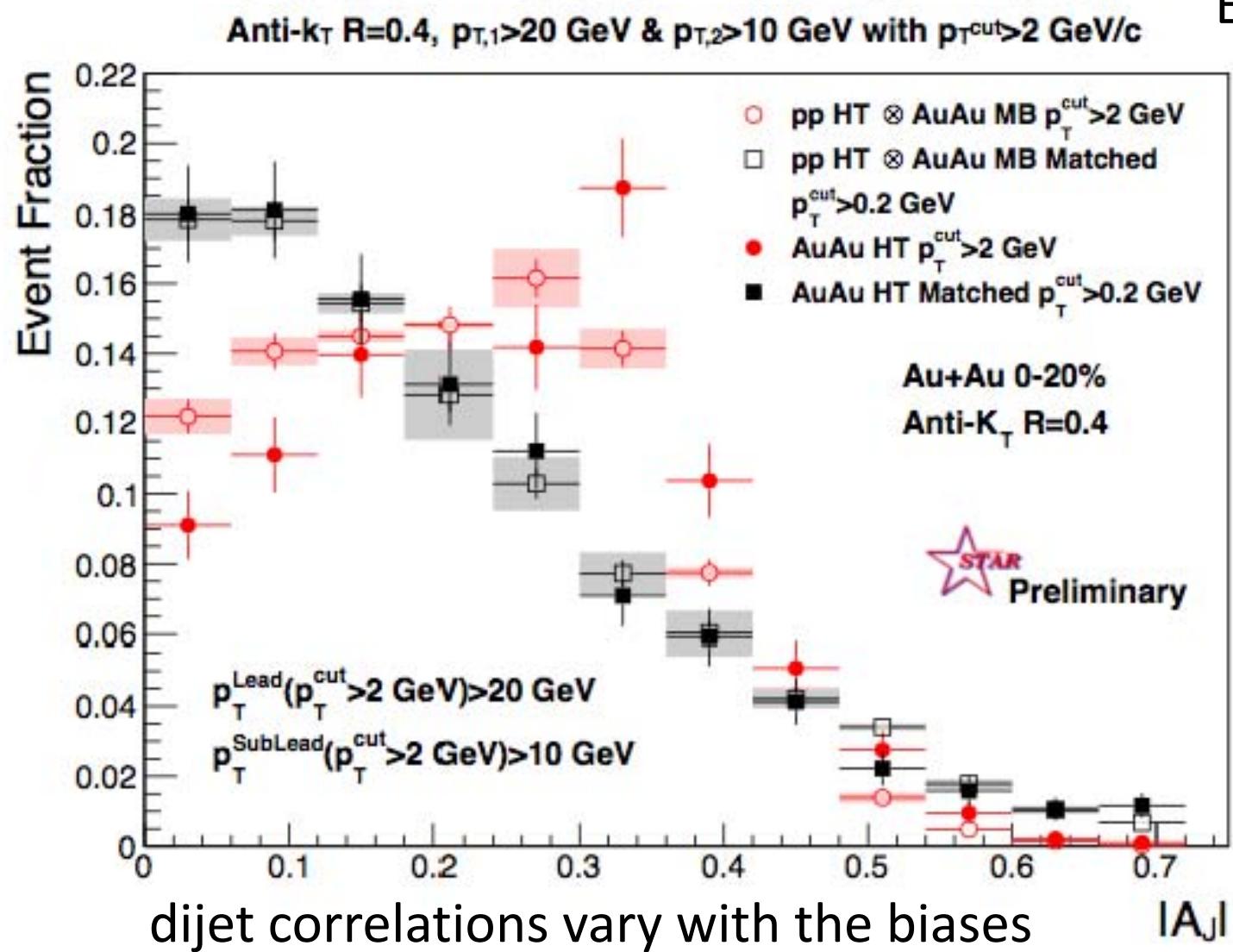


strategy: require a hard component (track jet or high energy cluster) in the reconstructed jet



R = 0.4 jets $\sim 90\%$ purity at 25 GeV with PYTHIA fragmentation

$$A_J = \frac{E_{T,1} - E_{T,2}}{E_{T,1} + E_{T,2}}$$



RHIC II Luminosities → New Frontiers

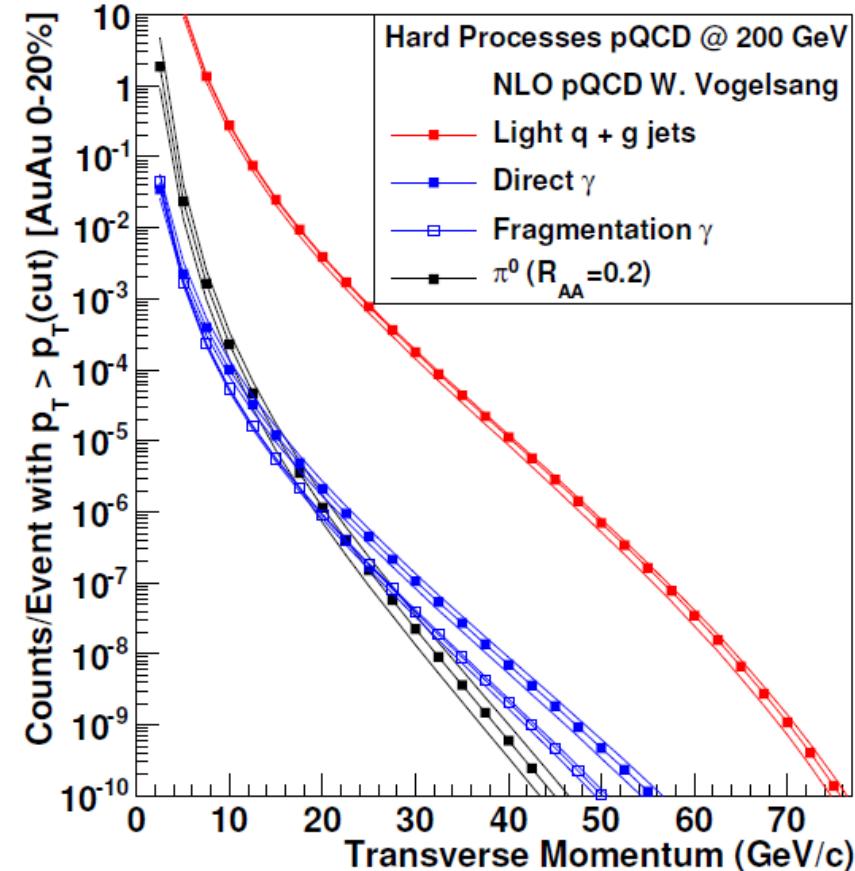
RHIC II + sPHENIX can record
50 billion events

within $|z| < 10\text{cm}$ in 20-weeks

Run-14 performance so successful,
same delivery would allow
sampling of **200 billion** events for
jets and direct photons

New C-AD projection will
allow Au+Au sampling of
0.5 trillion events

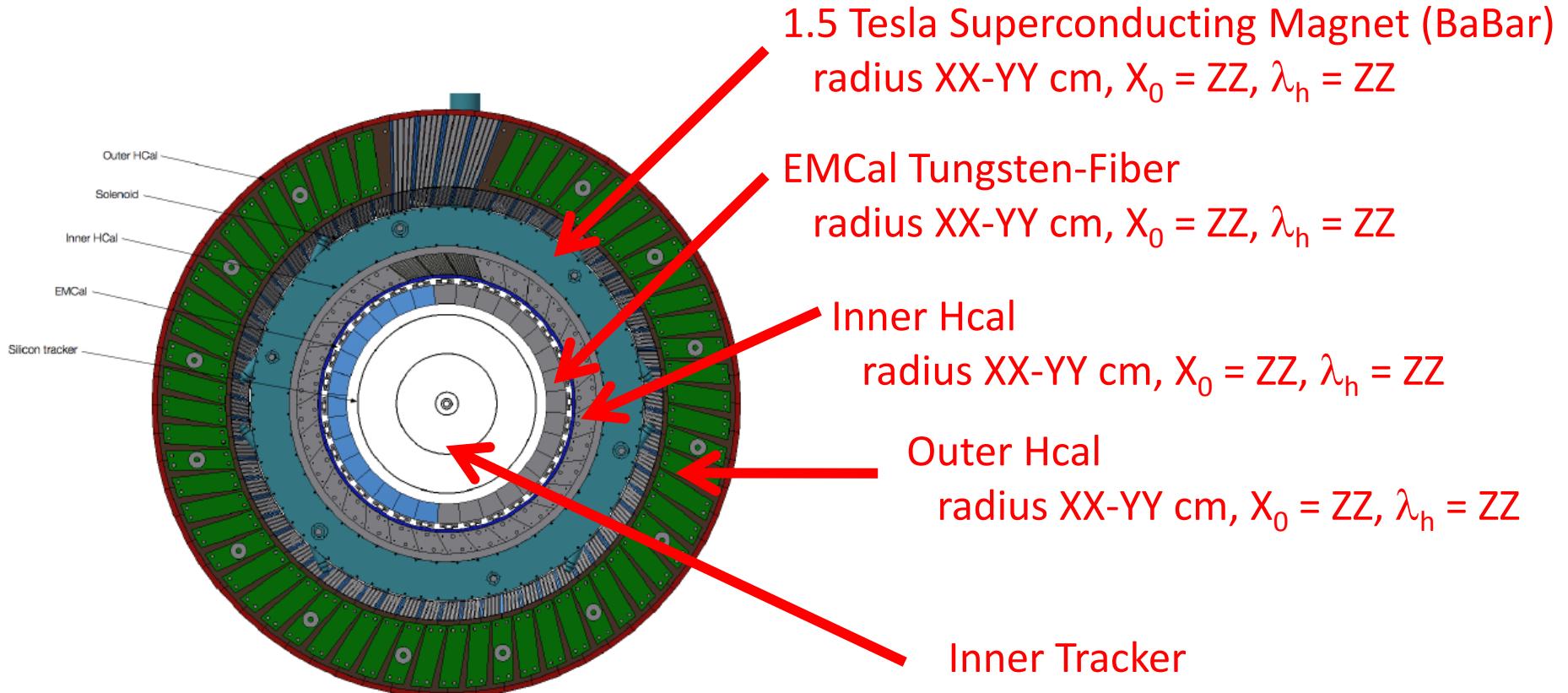
Critical similar statistics in
p+p and p+A



10^7 jets $> 20\text{ GeV}$ recorded
 10^4 photons $> 20\text{ GeV}$ recorded

e.g. 10^5 photons $> 20\text{ GeV}$ sampled
from $\frac{1}{2}$ trillion evts (S/B > 3)

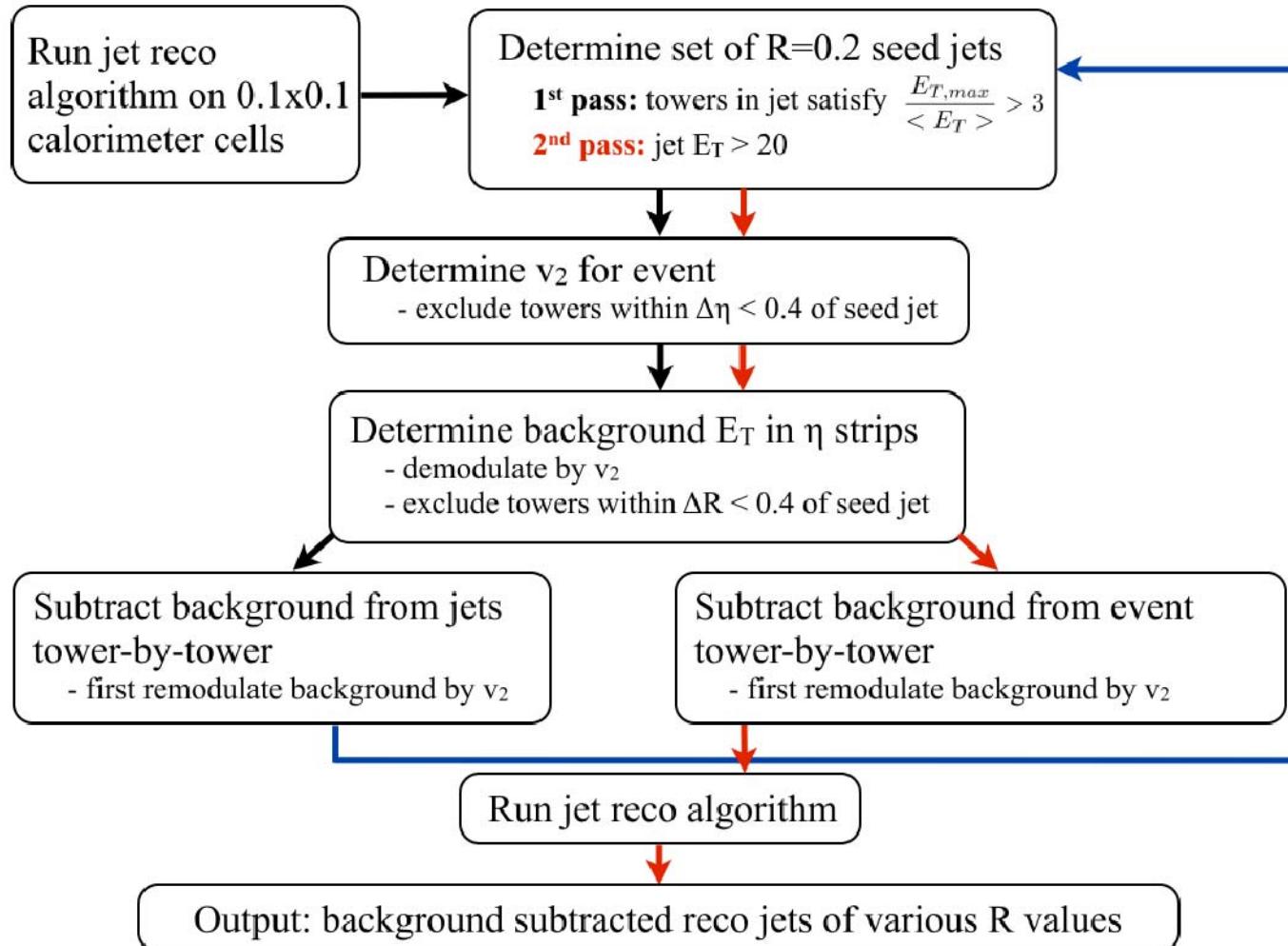
sPHENIX in a Nutshell



PHYSICAL REVIEW C 86, 054902 (2012)

Method for separating jets and the underlying event in heavy ion collisions at the NXL Relativistic Heavy Ion Collider

J. A. Gorda,¹ A. M. Goldin,² S. A. Cole,³ A. Fossa,⁴ M. P. McCumber,⁵ O. R. Mansouri,⁶ J. L. Nagle,⁴ C. S. O’Reilly,¹ B. Schenkel,¹ G. Stedtner,³ M. van Goolstok,³ and M. Guo⁷



v_2 modulation added to the HIJING events and removed by the algorithm

sPHENIX Front End

